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Medication dispenser for narcotic rehabilitation patients

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Abstract — **This paper describes the design of a medication dispenser developed for narcotic rehabilitation programs. The dispenser holds up to four doses of medication and operates under remote supervision. A direct-into-mouth dispensing mechanism is a feature of the device. The mechanical dispenser mechanism includes a rotating barrel, medication tubes and dispensing slider unit. The electronic design involves a microprocessor PIC18F4550, stepper-motors, sensing devices a LabVIEW-based computer interface for remote supervisory control and monitoring. The dispenser stores medication and successfully delivers it directly into the mouth under remote supervision.**

Keywords: Dispenser, Medication, Medical Device.

I. INTRODUCTION

Narcotic drug dependency rehabilitation programs aim to break with the routines and habits relating to the acquisition and use of illicit drugs and so minimise the harm of such use[1]. This is a relatively long-term commitment (usually over years) and commonly involves regular pharmacy supply of narcotic replacement medication to patients. Inappropriate use of this prescribed medication limits the treatment's effectiveness, and some times can be lethal.

Most narcotic rehabilitation patients prefer take-away-doses (TADs) to daily pharmacy visits [2]. However, the risks with TADs include over-dosing, inappropriate use (eg intravenous instead of oral consumption), and dose diversion. Control of these risks would be aided with the use of a secure medication dispenser designed for this application. There are numerous existing medication dispensers [3-9]. Nevertheless, none of these devices are suitable in terms of functionality and security for use with narcotic rehabilitation patients. Current devices mainly operate as a reminder and are manually operated by users themselves.

The designed medication dispenser is intended for use in a remote medication administration system. The design is a novel and innovative concept enabling supervised secure delivery of medication to narcotic dependency patients, and aims to reduce the problems involved with the provision of TADs, and increase the effectiveness and efficiency of dependency rehabilitation.

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II. DESIGN OF THE MEDICATION DISPENER

A. Design Considerations

Use in narcotic dependency rehabilitation programs means there are a number of requirements driving the design of this medication dispenser. These include the following.

- Tamper-proof housing (if access has been forced, the evidence will be obvious)
- Contains multiple (up to four) TADs
- Dispenses multiple tablets (up to 5) for each TAD
- Delivers medication directly into the patient's mouth
- Remote control via the internet by a supervisor (including enabling of the device, dispensing functions and webcam-based patient supervision).

B. Mechanical Design

The prototype's central component is a dispensing mechanism. This mechanism (Figure 1) consists of a rotating *Barrel (1),* extendable delivery *Tubes (2)*, a *Linear Carriage (3)*, a dispensing *Slider* unit *(4)* and three *Stepper Motors (5, 6, 7).* Inside each tube is a tablet *Push-rod.*

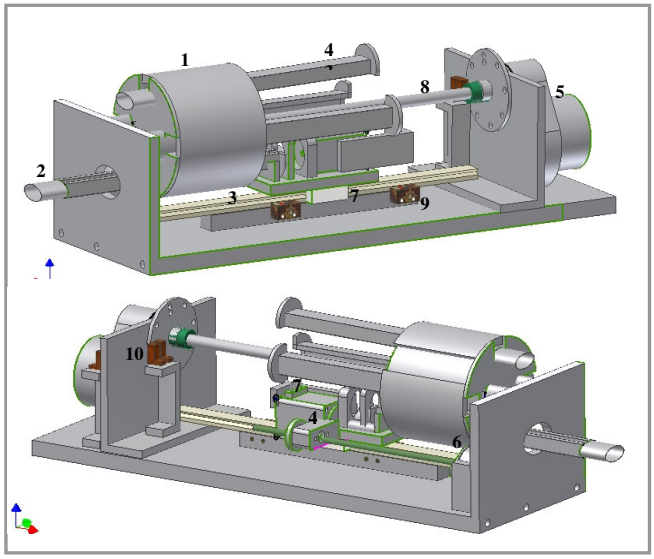

Figure 1: Dispensing mechanism (the top cover of the dispenser housing has been removed)

The sequence of the overall system operation is as follows. Tablets are loaded into the tubes in the pharmacy, with a

single TAD in each tube. The barrel rotates to select a tube. The slider is activated to extend a tube from the dispenser. A patient places their mouth over the end of the tube. The push-rod is then extended to push the tablets from the tube into the patient's mouth.

The motors drive the dispensing mechanism as follows.

-- *Motor-1 (1),* a unipolar stepper motor, turns the *main shaft (8)*, and rotates the barrel which enables tube selection.

-- The rotary motion of *Motor-2 (5),* a bipolar stepper motor, transmits into linear motion of the slider unit along a linear carriage through a 'lead-screw' assembly (threaded shaft and nut). This allows the slider unit to move forward and backward. The dispensing slider unit is designed to engage with the medication tube as the tube rotates into position. The selected tube then moves with the slider unit.

-- *Motor-3 (7),* a bipolar stepper motor, is mounted on the *slider* and used to push the push-rod to eject tablets.

-- *Microswitches (9)* and an *optical sensor (10)* are used in limiting the travel distances of the *slider* and *barrel*, respectively. The Microswitch is triggered whenever the slider unit reaches the limits of the desired travel, corresponding to the tube being fully extended or fully retracted. The optical sensor is activated whenever a tube aligns with the slider unit.

C. Electronic Design

The dispensing process is controlled by a *PIC18F4550* microcontroller. The microcontroller is connected to other peripheral devices, as in Figure 2. The system is powered from a 12V battery.

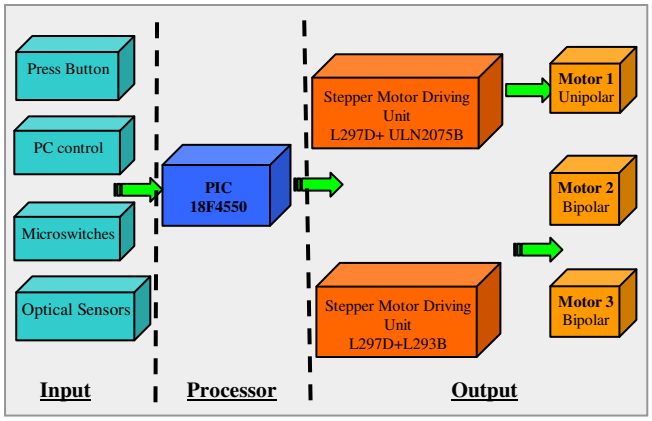

Figure 2: Block diagram of the microcontroller connection

The microcontroller receives signals from a computer – through a user interface, and from an external *press-button* - which mounted on the dispenser housing. The microcontroller then sends signals to the stepper motors via the stepper motor driving units. The output signals from micro-switches and optical sensor are used as interrupt signals to stop the motion of the stepper motor.

The stepper motor drivers *L297D* enable control of the stepper motors using only clock, direction and *drive mode* input signals, thus the burden on the micro-controller and the programming complexity are reduced significantly. In the dispensing process, the clock and direction signals are controlled by the microcontroller. The drive mode input signal is set as constant (LOW voltage level) corresponding to *two phase on full step mode* for the phase sequence generation.

The output phase sequences connect either to quad Darlington switches (ULN2075B) or to push-pull drivers (L293B.A). The Quad Darlington chip is used with the unipolar stepper motor to provide a sinking source for the currents from the unipolar stepper motor phases. Push-pull driver chips are used with the bipolar stepper motors because they require higher operating power. The two bipolar stepper motors operate asynchronously – this allows one driving circuit to be used with these two motors.

The schematic diagram for the electronic components is shown in the Figure 3.

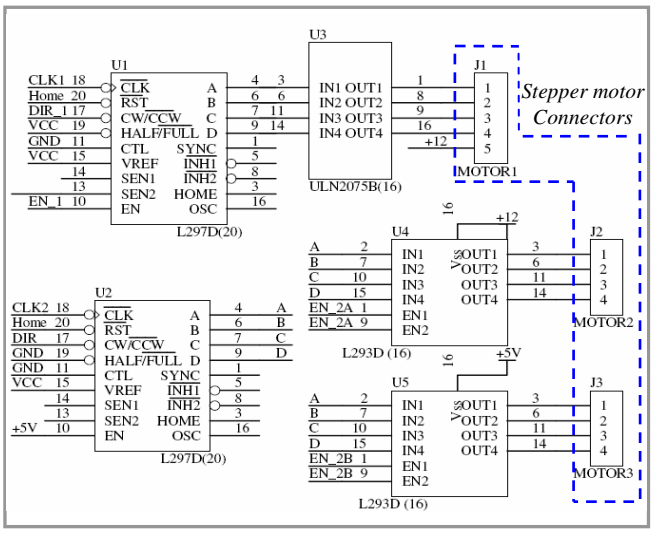

Figure 3: Schematic diagram of Stepper Motor Driving Unit

D. Dispensing Operation

The dispenser operation (Figure 4) is as follows. The dispenser starts and the mechanical and electronic components are reset to their initial states. In order to perform a dispensing cycle, Motor-1 turns on and rotates the barrel to the dispensing position, which is detected by the PIC through activation of the optical sensor. In this position the tube engages with the *slider* and also aligns with the external opening on the dispenser housing. Motor-2 then turns on to slide the dispensing slider unit outward along the linear carriage to extend the tube out of the dispenser housing. A Micro-switch activates to stop the movement when the unit reaches its fully-extended position. For dispensing medication, Motor-3 operates to extend its shaft, extending the push-rod to eject tablet(s). The tube can contain up to five tablets, and the maximum extension length of Motor-3 corresponds to this distance. The timing of the extension of the motor shaft is controlled by an external press button activated by the patient. The patient therefore has control of the timing of the release of the tablets into

their mouth. The dispensing cycle completes with the mechanism moving back to its initial position ready for the next dispensing cycle.

E. Program Description

The micro-controller *PIC 18F4550* is the "*heart*" of the dispensing device. It controls the dispensing operation, interacts with the sensing signals, stores the dispensing information, and communicates with the PC via a RS-232 serial cable.

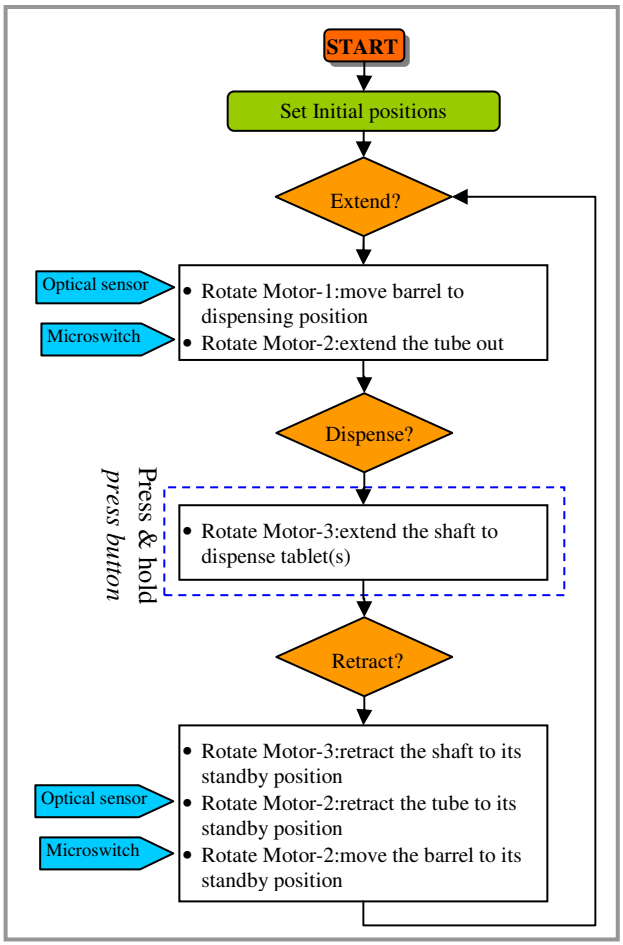

Figure 4: Block diagram of the dispensing cycle

Features of the micro-controller, which are used in programming, are:

- Interrupts: external interrupts, communication interrupts
- Read/Write EEPROM
- Universal Synchronous Asynchronous Receiver Transmitter (USART)
- ADC converter.

The device's outstanding feature is its ability to detect possible errors. If an error occurs, the device will be stopped immediately and inform the supervisor through the interface. This enables real-time problem identifying and triggers quick response. Errors are defined as shown in the Table 1.

Problem	Description
Insufficient supply Power	Supply power less than 12V
Serial Connection	No connection between dispenser and PC
Barrel related problem	Barrel not reach the defined position, due to: - optical sensor not working, or not working properly - barrel get stuck or has external interfere
Tube related problem	Tube not reach the defined position, due to: - micro-switch not working or not working properly - tube get stuck or external interfere
Medication empty	There is no medication in any of the four tubes
Sudden stop	Emergency stop command

Table 1: Table of error types

F. PC-based supervisory control

The supervisor's interface is developed in Labview (Figure 5). The supervisor controls the dispensing step by step, as follows: (1) *Extend* – extend the tube out to of the dispenser housing, (2) select the number of tablet(s) to dispense; (3) *Authorise* – authorizing to dispense; (4) *Retract* – moving the tube back and completing the process.

Other functions which are controlled through the interface are:

- *Stop*: stop the device operation immediately when this command executed
- *Reset*: this drives the barrel back to its last standby position and executes only if the Stop command has occurred
- *Initialisation*: drive the dispenser to its initial position
- *Power*: check the voltage level of the supply battery.

The supervisor is required to log on using a *string* password and has an "*active area*" to monitor the device's operation, which includes the currently executing command, errors and power level.

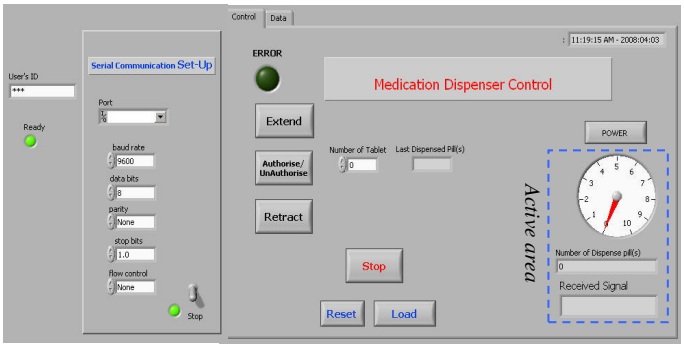

Figure 5: Labview User Control Interface

III. CONCLUSION

The dispenser is a novel design which enables secure direct-to-mouth delivery of medication. It is designed especially for use in narcotic rehabilitation programs. Trials on real patients to assess the design's utility and reliability are planned for future development and refinement.

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